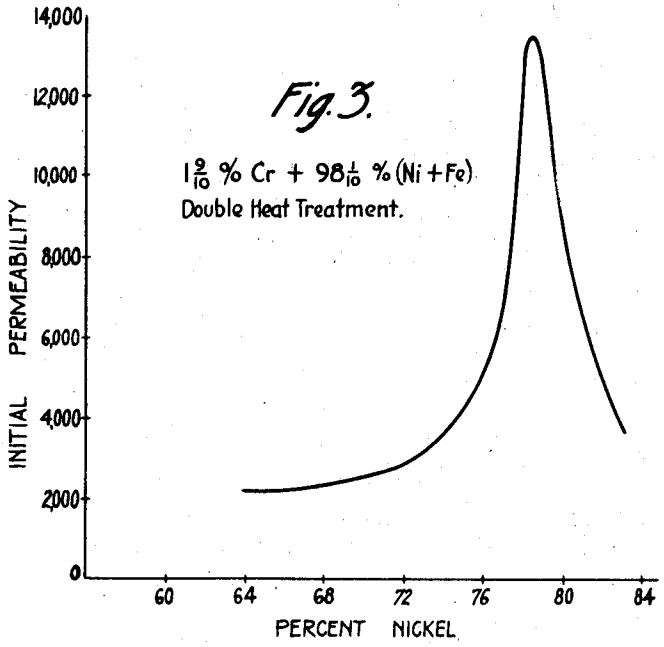
June 24, 1930. G. W. ELMEN 1,768,237

MAGNETIC MATERIAL

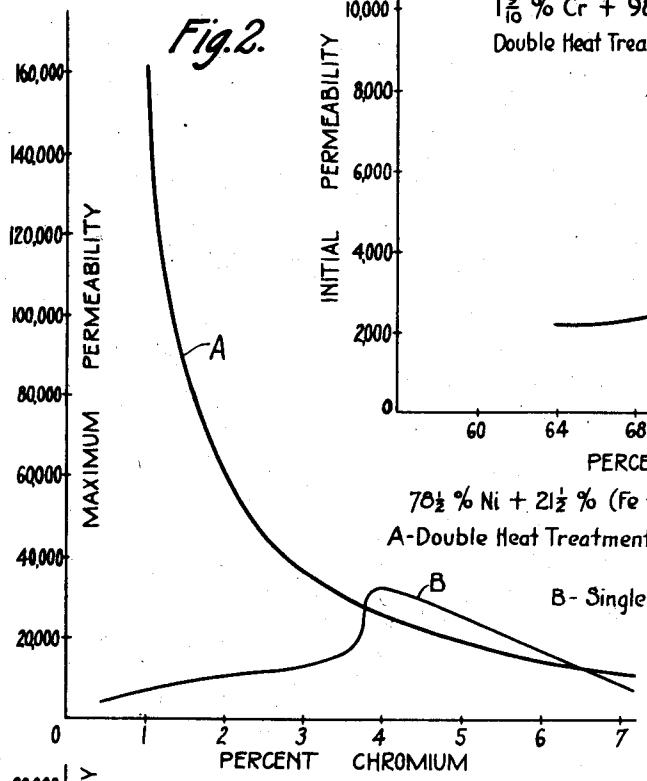
Filed Aug. 5, 1925 5 Sheets-Sheet 1

Fig. 3.



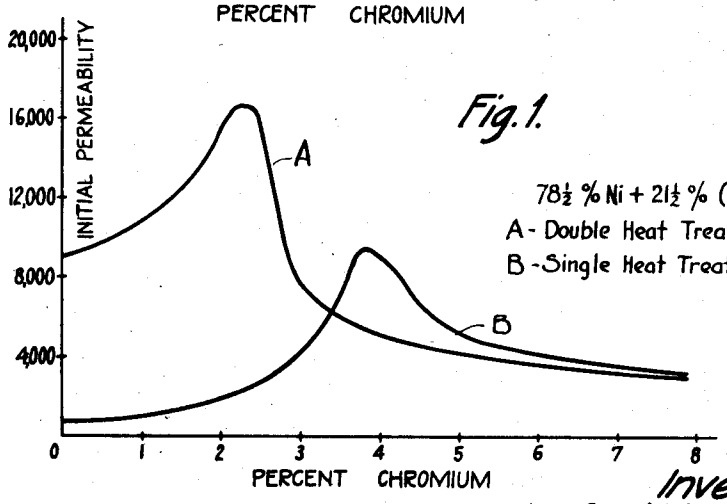
$1\frac{9}{10}$ % Cr + $98\frac{1}{10}$ % (Ni + Fe)
Double Heat Treatment.

Fig. 2.



$78\frac{1}{2}$ % Ni + $21\frac{1}{2}$ % (Fe + Cr)
A-Double Heat Treatment
B- Single Heat Treatment

Fig. 1.



$78\frac{1}{2}$ % Ni + $21\frac{1}{2}$ % (Fe + Cr)
A - Double Heat Treatment
B - Single Heat Treatment

Inventor:
Gustaf W. Elmen
by E. W. Adams. Atty.

June 24, 1930. G. W. ELMEN 1,768,237

MAGNETIC MATERIAL

Filed Aug. 5, 1925 5 Sheets-Sheet 2

Fig. 4.

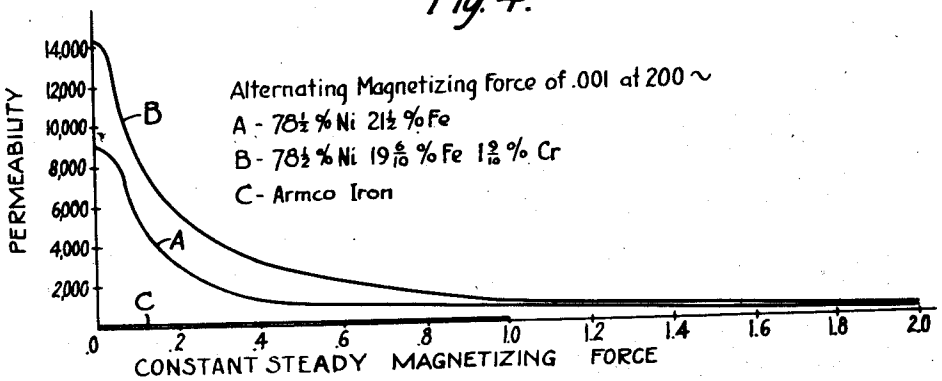


Fig. 5.

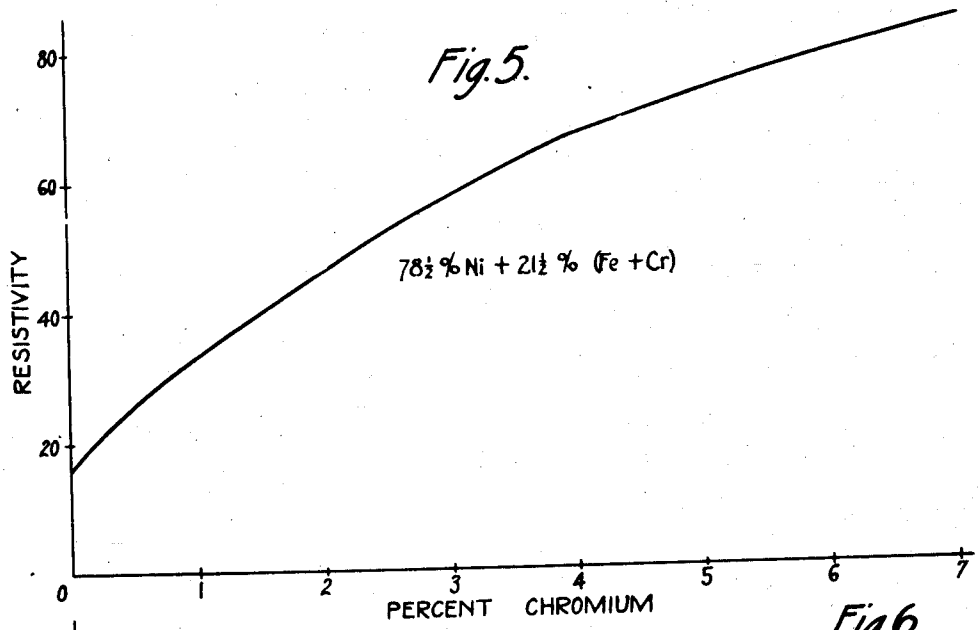
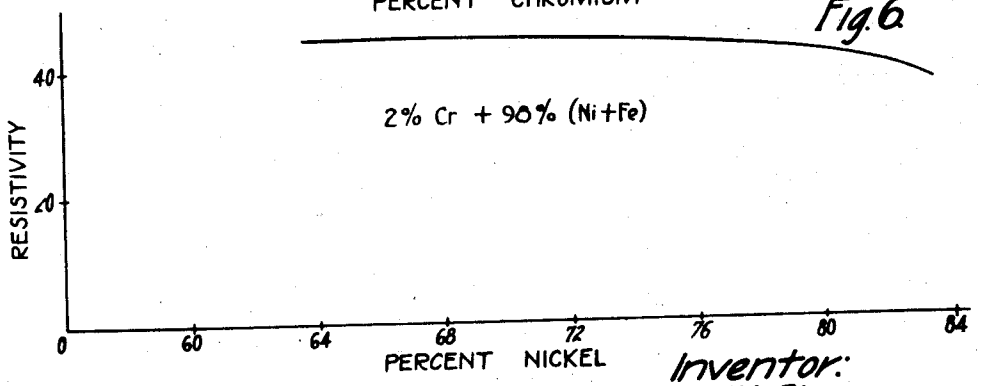


Fig. 6



Inventor:
Gustaf W. Elmen
by E. W. Adams Atty.

June 24, 1930. G. W. ELMEN 1,768,237

MAGNETIC MATERIAL

Filed Aug. 5, 1925 5 Sheets-Sheet 3

Fig. 7.

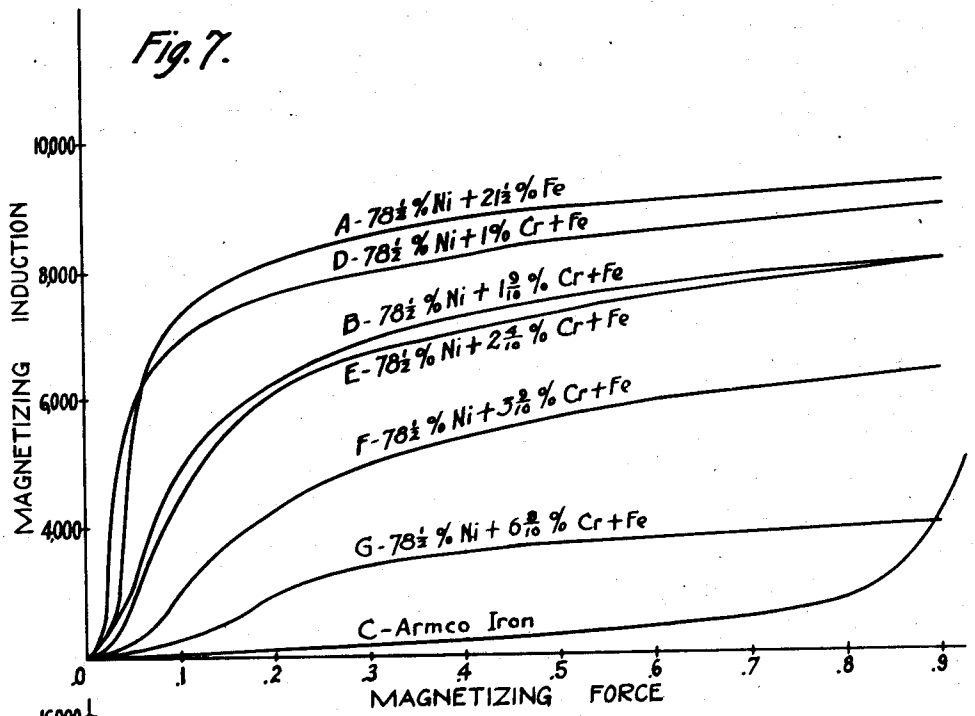
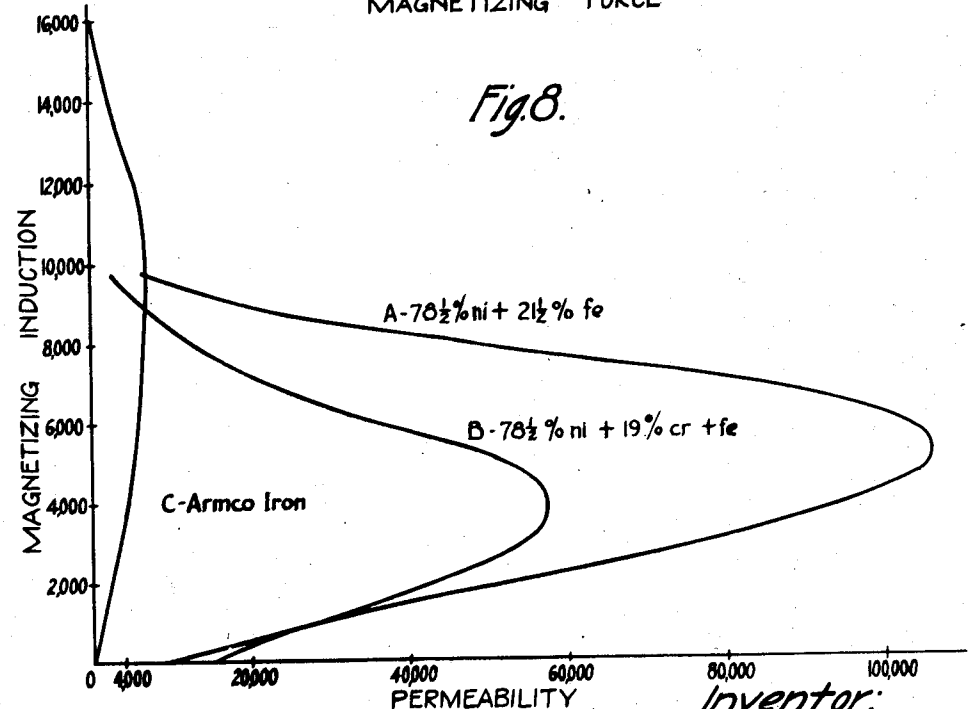


Fig. 8.



Inventor:
Gustaf W. Elmen
by E. W. Adams Atty.

June 24, 1930. G. W. ELMEN 1,768,237

MAGNETIC MATERIAL

Filed Aug. 5, 1925 5 Sheets-Sheet 4

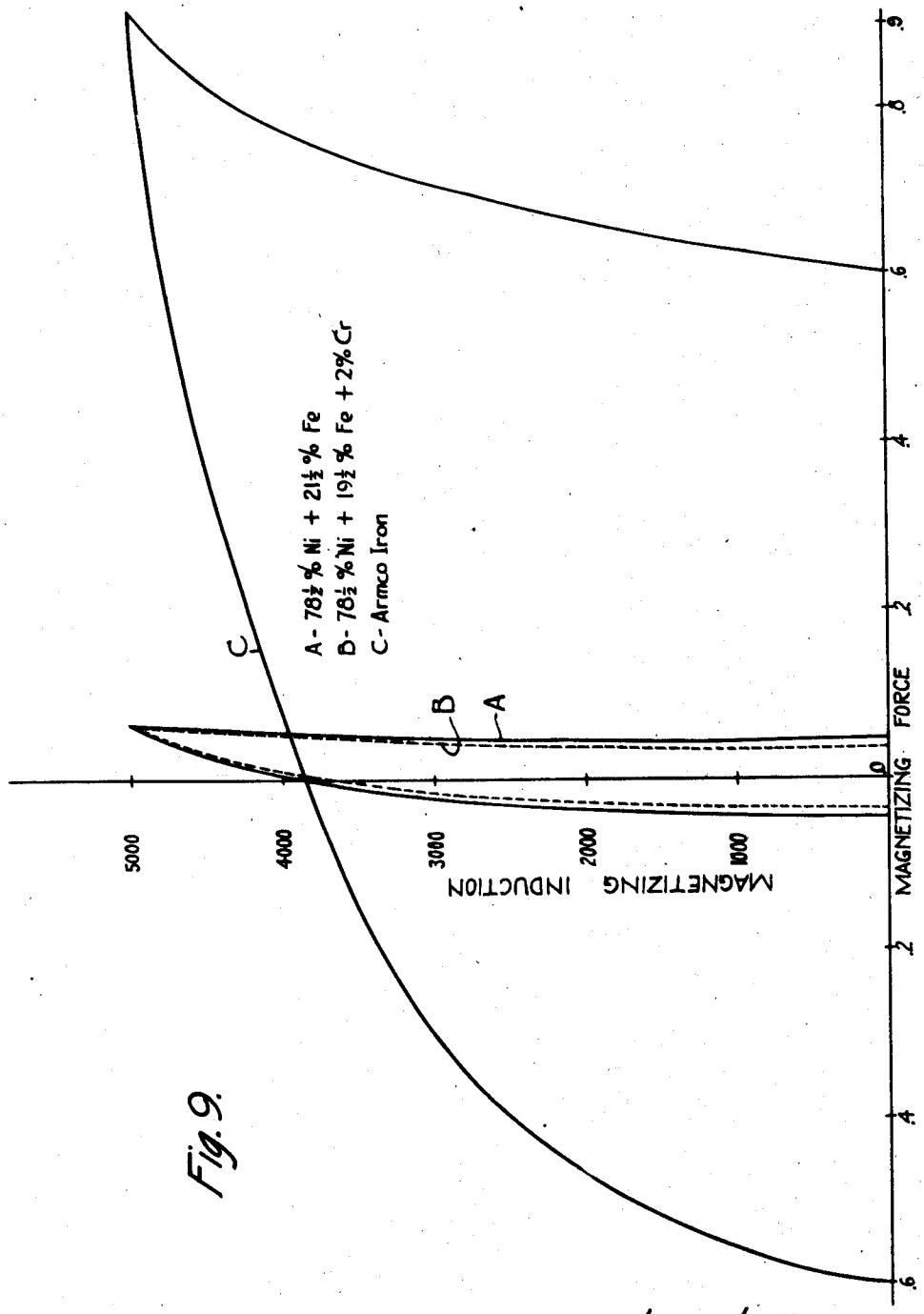


Fig. 9.

Inventor:
Gustaf W. Elmen
by E. W. Adams Atty.

June 24, 1930. G. W. ELMEN 1,768,237

MAGNETIC MATERIAL

Filed Aug. 5, 1925 5 Sheets-Sheet 5

Fig. 10.

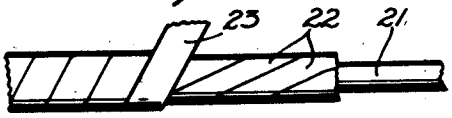


Fig. 11.

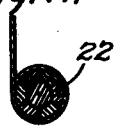


Fig. 12.

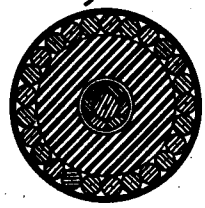


Fig. 13.

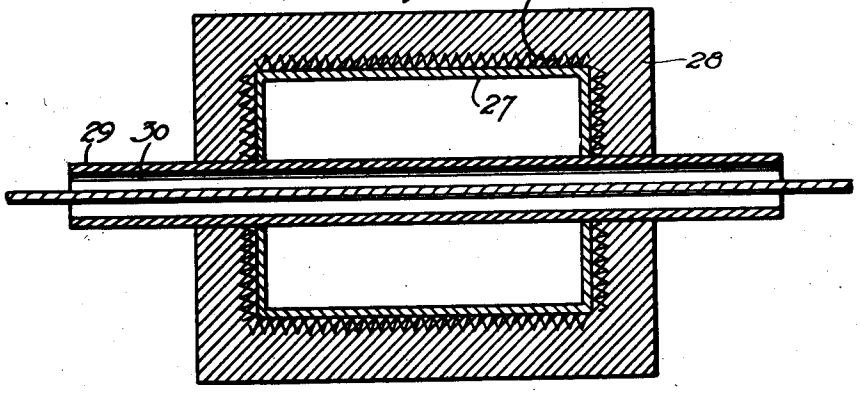


Fig. 14.

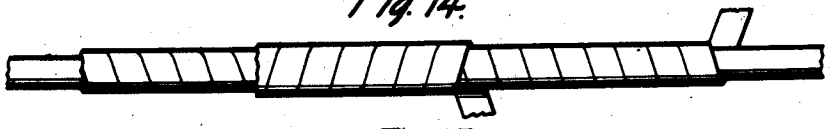
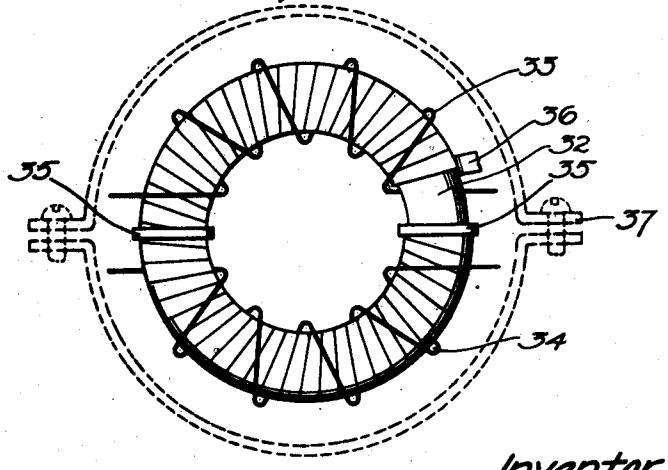


Fig. 15.



Inventor:
Gustaf W. Elmen
by E. W. Adams. Atty.

Patented June 24, 1930

1,768,237

UNITED STATES PATENT OFFICE

GUSTAF W. ELMEN, OF LEONIA, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

MAGNETIC MATERIAL

Application filed August 5, 1925. Serial No. 48,188.

This invention relates to new materials or substances having certain desirable magnetic qualities, among which are high magnetic permeability especially at low magnetizing forces, and low hysteresis and eddy current losses.

It is the principal object of the invention to provide a magnetic material which will be particularly suitable for use under conditions where the magnetizing forces are very small, such as is the case, for example, in the inductive loading of signaling conductors to increase their range and speed of operation. Another object relates to applying this loading material to a conductive core in a manner to produce a highly efficient transmission line for long range, high speed signaling. Another object is to improve the electrical and magnetic properties of magnetic materials of the type useful for loading signaling conductors and in particular to increase their resistivity with no material decrease or an actual increase of their permeability at low magnetizing forces and with little increase or with an actual decrease of their hysteresis losses. These and other objects will become apparent on consideration of examples of practice thereunder which will be disclosed specifically in this specification, with the understanding that the definition of the invention will be given in the appended claims.

This application is in part a continuation of application Serial No. 486,009, filed July 20, 1921, now patent 1,586,883, granted June 1, 1926.

Iron, because of its quality of high magnetic permeability has always been considered indispensable for the cores of tractive electromagnets, for dynamos, motors, telephone receivers, telegraph relays, etc.

Silicon steel exhibits magnetic qualities superior to ordinary iron in some respects, but its employment is limited by its comparative brittleness and the difficulty of working it. A good quality of soft iron has therefore been commonly employed as the best magnetic medium for general use for tractive electromagnets. The principal possible rivals of iron are nickel and cobalt but they are far below iron in permeability at the magnetizing forces involved in such apparatus. With nickel and cobalt, in this respect, stands Heusler's alloy of aluminum, manganese, and copper. It has been found that a composition of about ⅔ nickel and ⅓ copper, when tested at low magnetizing forces, gives a permeability higher than that of iron alone. It will be seen that with the exception of aluminum, all these metals stand close together in their atomic weights and atomic numbers and in this specification the five elements manganese, iron, cobalt, nickel and copper, having the consecutive atomic numbers 25, 26, 27, 28 and 29 will be referred to as constituting the magnetic group of elements.

The present invention relates to improvements in magnetic materials of the type useful for application at low magnetizing forces such as are found in the magnetic materials employed in continuous loading of signaling conductors, and similar applications, as distinguished from power apparatus. However, the invention has to do generally with new and improved magnetic materials and their utilization in any commercial application where they are found useful is within the scope of the invention.

In my Patent 1,586,884, granted June 1, 1926 on an application which was in part a continuation of my copending application, Serial No. 111,080, filed July 24, 1916 there is described in detail an improved magnetic material consisting of elements of the so-called magnetic group, for example, nickel and iron, and having a permeability much higher than that of iron at low magnetizing forces of the order of a few tenths of a c. g. s. unit. In the Patent No. 1,586,883 previously referred to, there is described and claimed broadly a somewhat similar magnetic material in which a substance is added for the purpose of increasing resistivity. These magnetic materials are peculiarly suitable for use in the loading of long telegraph cables as described in a patent to O. E. Buckley No. 1,586,874, granted June 1, 1926.

The claims attached to the present specification are based in part upon certain species of invention divisible from those claimed in

the patents mentioned above and in part upon certain newly discovered facts not set forth therein. Prior to applicant's researches eventuating in extensive application of iron-nickel alloys, metals such as chromium, molybdenum, manganese, cobalt and silicon had not been employed in magnetic alloys composed of two elements of the magnetic group, especially of nickel and iron, for the purpose of improving their utility as magnetic materials for use in applications involving small magnetizing forces. Such materials when combined with iron and nickel, for example, had been employed for the purpose of making hard steels such as tool steels, anti-corrosive steels, and magnetic bodies of great magnetic retentivity and corrosive force. It has been discovered, with respect to chromium, which is claimed broadly as an ingredient of similar magnetic compositions in Patent 1,586,883, that here is a preferred range of chromium content not set forth in said patent. Addition of chromium within this preferred range enhances the beneficial results obtained from its use. It has also been discovered that variation of the chromium content over this preferred range, keeping the nickel content and the heat treatment constant, gives a maximum range of initial permeability around a certain chromium content. For different heat treatments the maximum initial permeability is at a different chromium content. There is here set forth for the first time a body of systematic data upon the magnetic properties of iron-nickel-chromium compositions at low magnetizing forces in correlation with data upon their resistivity. Equivalents for chromium have also been investigated. It has been found that molybdenum, for example, combines with iron and nickel with results similar to those secured in the case of chromium alone. For the purposes of the present specification the chromium group includes the metals chromium, molybdenum and tungsten. Uranium is theoretically deemed to be a member of the chromium group but for all practical purposes connected with the present invention, it is excluded from consideration. Other suitable substances for increasing the resistivity of iron-nickel magnetic alloys without seriously impairing their initial permeability are manganese, silicon and cobalt. These elements are noted to be of high melting point, that is, above 1150° C. They also form solid solutions when combined with iron-nickel compositions in amounts within the scope of the present invention. The so-called noble or rare metals are excluded from the scope of this invention even though they have high melting points, because their cost and scarcity render them unavailable as ingredients of magnetic compositions. Hence, when reference is made to metals of melting point above 1150° C. it is understood that ruthenium, rhodium, palladium, osmium, iridium and platinum, as well as uranium, are excluded for the purposes of this specification.

The present invention relates to a further improvement in this material and provides a new magnetic material comprising elements of the so-called magnetic group combined in suitable proportions and to which additional material has been added which increases the resistivity of the alloy. This alloy when subjected to a proper heat treament and guarded against undue stresses and other disturbing causes not only develops and retains an extremely high permeability at low magnetizing forces of the order of a few tenths of a c. g. s. unit but at the same time has low hysteresis and eddy current losses. Furthermore it can be applied with advantage to the continuous loading of signaling conductors in such a manner as to obtain the full benefit of the above noted desirable properties.

The invention may be more clearly understood by reference to the accompanying drawing in which Fig. 1 comprises curves showing the variations in initial permeability of a nickel and iron alloy containing approximately 78½% nickel and 21½% iron, when various amounts of the iron content are replaced by equal amounts of a third substance, in this case, chromium.

Fig. 2 shows the variations in maximum permeability under conditions similar to those of Fig. 1.

Fig. 3 is a curve showing the variations in initial permeability of a magnetic material with variations in the proportions of nickel and iron when a third substance is held at a constant percentage.

Fig. 4 shows the variation in permeability of a preferred composition of this material, compared with Armco iron and a high permeability nickel iron alloy, for a constant alternating magnetizing force upon which is superimposed a varying direct current magnetizing force.

Fig. 5 shows the variation in resistivity with varying percentages of chromium added to an alloy of nickel and iron.

Fig. 6 shows the variation in resistivity when the percentage of chromium is maintained constant and the ratio of nickel and iron varied.

Fig. 7 comprises magnetization curves for various compositions of this magnetic material in comparison with similar curves for a high permeability nickel-iron alloy and for Armco iron.

Fig. 8 comprises curves showing the variations in permeability with varying magnetic induction of the preferred composition as compared with the materials of Fig. 7.

Fig. 9 shows half of a hysteresis loop of the improved magnetic material compared with

hysteresis loops for a high permeability nickel-iron alloy and Armco iron under similar conditions.

Fig. 10 is an elevation of a conductor loaded with the improved magnetic material of this invention.

Fig. 11 is a cross-sectional view of the same.

Fig. 12 is a cross-section of the same conductor when embodied in a submarine cable.

Fig. 13 is a sectional view of a type of furnace suitable for annealing the loading conductor.

Fig. 14 is an elevation of a conductor wrapped with two layers of this magnetic material.

Fig. 15 shows a loading coil with its core of this material and its windings indicated diagrammatically.

Referring now more particularly to Fig. 1, the curves A and B show the effect upon the initial permeability of a magnetic alloy comprising 78½% nickel and 21½% iron when varying percentages of a third substance, in this case chromium, are added to replace an equal amount of iron, curve A being for one heat treatment and curve B another.

The initial permeability as defined in my copending application referred to above is the permeability for zero magnetizing forces. This value is obtained by determining a series of values for exceedingly low forces, say of the order of .01 to .05 c. g. s. units. The results plot linearly and may be extrapolated back to the value for H=O, thus giving the value of permeability for zero magnetizing forces.

The heat treatment for curve A consisted in annealing by slow cooling from 1100° C., followed by heating to 600° C., and then cooling to room temperature at a rapid predetermined rate, namely, 9.5° per second. In accordance with a slight modification of this heat treatment giving the same results, the material is first heated to the desired temperature and then cooled slowly to a temperature near the magnetic transition temperature and then cooled rapidly at a predetermined rate which is intermediate an annealing rate and a rate at which undue stresses and strains will be set up in the materials. Curve B represents the same conditions as curve A except that the heat treatment consisted only of the annealing.

The proportions of 78½% nickel and 21½% iron were selected for preliminary tests since approximately these proportions had previously been found to give the highest permeability when chromium or other substance which behaves similarly was not present. Both of the curves show that with the respective heat treatments the substituting of a small amount of chromium for an equivalent amount of iron causes an increase in initial permeability. When the material is given the double heat treatment as represented by curve A the initial permeability reaches a maximum when slightly more than 2% cromium by weight is used and then decreases rapidly with larger amounts of chromium. In the case of the single heat treatment as shown by curve B the maximum initial permeability is reached when the material contains approximately 4% chromium by weight and decreases less rapidly with larger amounts of chromium.

The effect upon the maximum permeability of an alloy containing 78½% nickel and 21½% iron when varying amounts of the iron are replaced by equal amounts of chromium is shown graphically in Fig. 2. In obtaining the data for curve A the magnetic material was subjected to the same double heat treatment as was used in the test represented by curve A of Fig. 1. From an examination of this curve it will be seen that the maximum permeability decreases very rapidly with an increase of chromium. Thus for an alloy containing 1% chromium there was obtained a maximum permeability of 150,000, for an alloy containing 2% chromium the maximum permeability was decreased to 60,000 and for an alloy containing 7% chromium, the maximum permeability is approximately 10,000. When the magnetic material is subjected to a single heat treatment as illustrated by curve B, the maximum permeability increases with the chromium content until a chromium content of approximately 3½% is reached, the maximum permeability then increases rapidly and the curve crosses curve A (which relates to the same composition given the double heat treatment) and remains above the curve A until the chromium content approaches 7%.

As a result of the discoveries represented by the curves of Figs. 1 and 2 it was seen that an alloy containing approximately 2% chromium, when properly heat treated would be very satisfactory from the standpoint of permeability.

In order to obtain a further indication, then, of the most satisfactory proportions of nickel and iron, thorough tests were made in which the chromium content was maintained constant at 1.9% and the proportions of nickel and iron varied. The results of these tests which are shown on Fig. 3 indicate that the most satisfactory results are obtained with approximately 78½% nickel and the balance iron and a third substance of which chromium is the specific example dealt with in the present instance. As indicated by the curve of Fig. 3, the initial permeability curve rises very rapidly as the nickel component approaches 75%, reaching a maximum at approximately 78½% nickel and then decreasing rapidly with further increases in the nickel content. These tests were supplemented by tests on other nickel-iron chromium al-

loys containing up to 8% chromium and in each case the highest permeability was obtained when the nickel content was approximately 78½%. Similar tests were also made with substances other than chromium. For example, with small amounts of cobalt, silicon, manganese and molybdenum, as high or higher permeabilities were obtained when the nickel content was approximately 78½% of the whole as when any other percentage was used. The expression "resistance increasing material" will be used hereinafter to include metals of melting point above 1150° C., such for example, as chromium, molybdenum, maganese, cobalt and silicon, and other similar common metals and combinations of these elements. The addition of still other elements or substances for the same or other purposes, thereby producing compositions within the scope of the appended claims, is not deemed to be a departure from the invention.

In Fig. 4 are curves showing variations in alternating current permeability of various magnetic materials when subjected to a 200 cycle alternating current magnetizing flux of .001 c. g. s. units and upon which is superimposed varying direct current magnetizing forces. Curve A shows the permeability of an alloy containing 78½% nickel and 21½% iron. Curve B shows the improved magnetic material containing 78½% nickel, 1.9% chromium and the blance iron and curve C shows the alternating current permeability of a very pure grade of magnetic iron. From these curves it will be seen that the improved magnetic material containing approximately 2% chromium when subjected to a superimposed direct current magnetizing force within the limits employed in this figure has a considerably higher alternating current permeability than an alloy containing 78½% nickel and the balance iron, and has a decidedly higher A. C. permeability than the best grade of magnetic iron. The importance of this characteristic of the material is apparent since loaded lines and various kinds of apparatus such as relays, telephone receivers and repeating coils are constantly subjected to a greater or lesser direct current magnetizing force upon which is superimposed a varying magnetizing force resulting from voice and signaling current.

In Fig. 5 is shown the variation in resistivity of an alloy containing 78½% nickel and the balance iron and chromium for different proportions of the latter two elements. It will be noted that the resistivity of the alloy increases rapidly with an increase in the amount of chromium present in the alloy.

The curve of Fig. 6 shows the variation in resistivity of an alloy containing approximately 2% chromium and the balance nickel and iron with varying proportions of the latter two elements. As shown by this curve the variation in the nickel content produces slight change in the resistivity of the material.

The curves shown in Fig. 7 comprise a series of magnetization curves for the improved magnetic alloy with various percentages of chromium in comparison with a nickel-iron alloy containing 78½% nickel and 21½% iron and a very pure grade of magnetic iron. The nickel-iron alloy and the various nickel-iron-chromium alloys were given the double heat treatment previously referred to and the iron sample was heat treated to bring out its best magnetic characteristics. Curve A is the magnetization curve for the nickel-iron alloy containing 78½% nickel and 21½% iron. Curve B, which is the improved magnetic material containing 78½% nickel and approximately 2% chromium with the balance iron, rises less rapidly than curve A except at a point near the origin and saturates at a considerably lower value. Both, however, are far above the curve for Armco iron as represented by curve C which has not even begun to rise steeply at the low magnetizing forces with which we are now chiefly concerned. Curve D is a magnetization curve for a nickel-iron alloy containing approximately 78½% nickel, .98% chromium and the balance iron. Curves E, F and G are for similar alloys containing respectively 2.37%, 3.86% and 6.85% chromium. These curves show that for a given magnetizing force above .025 c. g. s. units, the permeability is decreased with an increase in the chromium content. It also may be seen that the magnetizing force necessary to produce maximum permeability increases with an increase in the chromium content. Additional tests made with the same samples (not shown in the drawing) indicate that with extremely slow cooling (annealing in the furnace) practically the reverse is true, the permeability for a given magnetizing force increasing with increase in the chromium content and the point of maximum permeability being decreased with an increase in the amount of chromium present. These tests further show that alloys containing 3% or more of chromium are less sensitive to heat treatment than are those containing less chromium. Therefore, by using alloys containing larger amounts of chromium, it is possible to obtain a more uniform product under ordinary commercial process although this uniformity is obtained at a sacrifice of permeability.

The curves of Fig. 8 are obtained by plotting the permeability values of the materials of Fig. 7 against the values of magnetic induction. Curve A is the curve for nickel-iron alloy containing 78½% nickel and 21½% iron. Curve B is the curve for the similar material in which approximately 2% of the iron is replaced by chromium and curve C is the curve for Armco iron under similar conditions.

The hysteresis curves of the three materials of Figs. 7 and 8 are shown in Fig. 9, only the upper half of the curves being shown. These curves are carried to a maximum induction of 5,000 c. g. s. units and are drawn on the same scale. Curve A is half of the hysteresis loop of the nickel-iron alloy containing 78½% nickel and 21½% iron. Curve B is a similar curve for an alloy represented by curve A in which approximately 2% of the iron is replaced by an equal amount of chromium and curve C is a similar curve for Armco iron. The hysteresis loop for the improved alloy containing chromium, while in this particular case slightly less than that of the similar alloy without chromium, is really of the same order but both have a very much smaller area (about $\frac{1}{16}$) than that of the loop of curve C for Armco iron.

It will also be noted from a study of the curves of Fig. 9, that the coercive force of the improved magnetic material, although slightly less, is of the same order as the coercive force of the alloy containing 78½% nickel, 21½% iron, and is much less than the coercive force for the best grade of magnetic iron as represented by curve C. After being subjected to a magnetizing force of 100 c. g. s. units, the coercive force of the nickel-iron alloy containing 78½% nickel and of the improved magnetic alloy containing approximately 2% chromium is of the order of .05 c. g. s. unit, whereas the coercive force for Armco iron is approximately .86 c. g. s. unit.

In the preparation of this magnetic material in its preferred form, iron and nickel may be fused together in an induction furnace, in the proportion of about 19½% iron and 78½% nickel, good commercial grades of these materials being suitable for this purpose, and to this alloy is then added the third substance such as chromium, which increases the resistivity of the material. However, in order to prevent excessive amounts of this substance from going into the slag, it has been found preferable to first make up an alloy of that substance with nickel and then add that alloy to a nickel alloy so proportioned as to give a desired proportion to the magnetic material when the two alloys are combined. For example, when it is desired to make a nickel-iron-chromium alloy containing approximately 2% chromium, an alloy of approximately 75% nickel and 25% chromium is first prepared and this alloy is added to a molten nickel-iron alloy while in the furnace so as to give the desired proportions to the material. After the three ingredients are added the composition is poured in a mold and cooled to form a thick bar or rod which is then rolled, swaged or otherwise worked into the form in which it is to be used. A suitable process for making and treating the material is disclosed in patent to J. H. White, No. 1,586,871, granted June 1, 1926.

When the material is to be used for the continuous loading of signaling conductors, the bar or rod as taken from the mold is subjected to repeated swaging and annealing operations or to hot rolling by which it is reduced in diameter and correspondingly elongated. The long rod thus formed is then drawn out by repeated drawing and annealing operations to a size about #20 B and S gage and is then formed into a thin tape by passing it between flattening rolls and by several such operations flattening it to a tape having a thickness of about .006 inches and a width a little more than .125 inches. In the last annealing operation the material is heated to a temperature of 1100° C. and then allowed to cool slowly thus carrying out the first step of the heat treatment which is not completed until after the tape is wound upon the conductor. This tape is next passed through cutting rolls or discs which trim its edges squarely on both sides and give the tape an exact and uniform width, thus placing it in condition for application upon the conductor. When it is desired to use the loading material in the form of wire, rather than tape, the drawing process is continued until the wire has the desired dimensions.

The stranded conductor of Figs. 10 and 11 comprises a central cylindrical wire 21 enveloped by six surrounds 22, which are shaped to fit together closely to form a cylindrical annulus about the central wire. It is desirable that the conductor assembled in this way have a smooth cylindrical contour and for this purpose it may be drawn through a die or subjected to a swaging operation. The stranded conductor as described has the advantages of flexibility and preservation of conductive continuity in case of breakage of any of the strands by a force not too severe to disrupt all the strands at the same place. This stranded conductor 21—22 is #5 B and S gauge in size and is loaded with the improved magnetic material in the form of tape as described above. The magnetic tape 23 is wrapped helically on the stranded copper core in accordance with my copending application Serial No. 557,928, filed May 2, 1922, now Patent No. 1,586,887, granted June 1, 1926, care being taken to abut the edges closely without overlapping. Apparatus for accomplishing this is described in detail in patent to Frederick S. Kochendorfer No. 1,624,668, granted April 12, 1927.

The taped conductor is next to be given the final step in its heat treatment and for this purpose it is drawn lengthwise through the furnace of Fig. 13 which is maintained at a temperature of about 900° C. This is a muffle furnace with the heating elements 26 between the fire clay muffle 27 and the fire brick 28. Around the fire brick 28 is a sheet iron outer wall. The iron tube 29 has a copper lining 30 the inside diameter of which

is a little over one-half inch. It extends clear across the furnace at each end and projects about eight inches beyond the furnace walls. The length of the pass through the furnace is about two feet and the rate of movement of the conductor therethrough is about three quarters of a foot per minute. As the taped wire passes from the furnace and the projected ends of the tube 29, it cools in the air which outside of the tube is kept at about normal room temperature, that is, about 20° C. Under the conditions and for the dimensions described, this gives a proper rate of cooling after heating in the furnace. The conductor should be led away straight from the furnace for a sufficient distance to permit it becoming well cooled, since bending at this stage may impair its permeability. Also the necessary coiling of the taped conductor should be on a large radius not less than two feet, since the strains involved in coiling and uncoiling on a smaller radious may lower the permeability.

After the heat treatment, the taped conductor is first insulated in such a manner that the loading material will not be subjected to uneven strains when the cable is submerged at great depths. This is preferably accomplished by coiling the taped conductor with liquid bitumen in accordance with the process described in detail in a copending application of Archie R. Kemp, Serial No. 617,511, filed February 7, 1923, now Patent No. 1,700,766, granted Feb. 5, 1929. It is then insulated, armoured and mechanically reinforced according to the usual practice for submarine cables by surrounding it with a layer of gutta percha and then with the usual wrapping of jute and a sheath of steel wires, giving the product as shown in cross section in Fig. 12.

While a certain speed and temperature of a certain type of furnace have been described to produce the desired results in the case of a particular cable, it is apparent that these factors may be varied or adjusted to meet different conditions, such for example, as a cable of different diameter from the one here disclosed.

A description has been given of the dimensions of the conductive core and the width and cross section of the loading tape specifically for a certain contemplated example of a long ocean cable for high speed telegraph transmission. In some cases where a thicker sheath is desired, it may be best to apply it in the form of two tapes wound in opposite directions one outside the other, as indicated in Fig. 14. Among the advantages of this construction are that, by applying the loading sheath in two layers instead of one, the eddy current losses are somewhat reduced and the fact that the layers are wound in opposite directions causes a more rugged structure for handling since the tape is less likely to slip or buckle. When more than one layer of loading material is used, the thin coating of oxide on each serves as an insulating material for reducing the eddy currents, but this coating may be purposely increased in thickness or insulating coatings may be applied to the loading material if desired.

With a conductor composed of the improved magnetic material containing approximately 2% chromium the attenuation losses are kept low since not only does the material have a low hysteresis factor but, because of its high resistivity, the eddy current losses are also kept at a minimum.

The improved magnetic material of this invention is useful for other purposes than for the continuous loading of signaling conductors. For example, it may be used advantageously in the magnetic circuits of telephone receivers, ringers and electromagnetic devices of various types. Because of its low coercivity, it is of particular importance in the magnetic circuits of moving vane meters, marginal relays, split phase relays, and similar devices in which the sensitivity of operation is influenced to a considerable degree by the previous magnetic history of the magnetic members. The low saturation point and the shape of the magnetization curves make this material extremely well adapted for use in the cores of frequency changers and magnetic modulators. Also, its characteristics are such as to make it a very desirable material for the cores of various types of transformers, such, for example, as those used for transmitting currents having a wide frequency range such as those which occur in the transmission of music and the voice. Because of its low hysteresis loss it is of particular advantage when used in the cores of distributing transformers which are continually connected to the line. Another use for which it is particularly adapted, is as a magnetic shield for shielding apparatus from extraneous magnetic fields. It is also useful for lump loading as well as for continuous loading. Choke coils of very high inductance and low resistance may be made up in remarkably small volume with a consequent saving of material and low cost of manufacture. Coils with cores of this material have been found particularly valuable for use as magnetic shunts in submarine telegraph receiving apparatus.

For loading coils small wires of the magnetic material are insulated from each other and wound into a core in the well known manner of making soft iron cores for loading coils. On this core the windings of the loading coils are mounted. Such a coil is shown in Fig. 15 with the core 32 on which the coil windings 33 and 34 are indicated diagrammatically. In order to give the core material stability or constancy in perme-

ability even though large currents are superimposed on the loading coil circuit, the core may be provided with gaps filled with non-magnetic material 35. The use of the improved magnetic material allows the necessary effective permeability to be secured even with these gaps present. The windings of the core 32 may be held together by wrapping the core with tape 36 of non-magnetic material and the core sections on each side of the non-magnetic gaps with the windings thereon may be held together by means of clamps 37.

Although for commercial reasons it will probably be advantageous to employ a single element as the substance for increasing the resistivity and the initial permeability of this material, it is, of course, obvious that several elements could be simultaneously employed to obtain one or more of the advantages as set forth in the specification without departing from the spirit of the invention.

Iron, in accordance with this specification, means iron as described in the literature of magnetic materials prior to August 1, 1925.

What is claimed is:

1. A magnetic composition comprising at least two elements of the magnetic group and other metallic substance composed of metals of melting point above 1150° C. which when added to magnetic compositions composed of such two elements increases the resistivity, characterized in that the proportion of such other substance is such as not to decrease the initial permeability.

2. A composition in accordance with the foregoing claim, further characterized in that the elements of the magnetic group include nickel and iron.

3. A composition in accordance with the second foregoing claim, further characterized in that the elements of the magnetic group are nickel and iron and the other substance is in a proportion which increases the initial permeability.

4. A magnetic composition in accordance with the third foregoing claim, further characterized in that the elements of the magnetic group include nickel and iron and the initial permeability obtained by the added substance is higher than that of iron.

5. A magnetic composition in accordance with the fourth foregoing claim in which the elements of the magnetic group are nickel and iron, characterized in this that the initial permeability of the composition when heat treated to produce high initial permeability is higher than can be produced by heat treating the composition with the other substance replaced by iron.

6. A magnetic composition of initial permeability higher than iron comprising nickel and iron, the nickel being more than 70% of the whole and including other metallic substance of melting point above 1150° C. whereby the resistivity of such compositions is increased.

7. A composition in accordance with the foregoing claim in which the nickel is from 75% to 85% of the composition.

8. A magnetic material comprising nickel, iron, and a third metallic element of melting point above 1150° C. to increase the specific resistance thereof and in which the nickel component is approximately 78½% of the whole.

9. A magnetic material comprising nickel and iron to which is added chromium in such amount as with proper treatment will produce higher initial permeability than when the nickel and iron alone are present.

10. A magnetic material comprising approximately 78½% nickel, and the remainder iron and chromium in such amount as with proper treatment will produce higher initial permeability than when the chromium is replaced by iron.

11. A magnetic material heat treated to have high permeability in a very low range of magnetizing forces comprising nickel, chromium and iron in which the nickel component consists of approximately 78½% of the whole, the chromium component not greater than 7% of the whole and the balance iron.

12. A magnetic material comprising nickel, chromium and iron in which the nickel component consists of approximately 78½% of the whole, the chromium component not more than 2½% of the whole and the balance iron.

13. A magnetic material comprising approximately 78½% nickel, approximately 2% chromium and the balance iron.

14. A magnetic material comprising approximately 78½% nickel, iron, and at least one other metallic element of melting point above 1150° C., and having a higher specific resistance than if said other element were replaced by iron.

15. A magnetic material comprising nickel, iron, and not to exceed 7% chromium, the nickel component being more than 70% of the whole, said magnetic material having those properties which are produced in such a composition by being annealed at a temperature of the order of 1100° C. and slowly cooled therefrom followed by bringing the material to a temperature of the order of 600° C. and then cooling rapidly to a temperature considerably lower than 600° C. at a rate intermediate an annealing rate and a rate at which undue stresses and strains will be set up in the material.

16. A magnetic material comprising nickel, chromium and iron in which the nickel component comprises approximately 78½% of the whole, the chromium component not to exceed 7% of the whole, and the balance iron, said material having the magnetic properties

which are produced by heating such a composition to 1100° C. and slowly cooling, then heating to 600° C. and cooling rapidly to a point lower than the magnetic transition point of the material.

17. A magnetic material comprising nickel, chromium and iron in which the nickel component comprises approximately 78½% of the whole, the chromium component from 2 to 5% of the whole, and the balance iron, said material having the properties which are produced in such a composition by being heated to a temperature around 1100° C. and slowly cooled and then heated to 600° C. and cooled slowly.

18. A magnetic material comprising approximately 78½% nickel, chromium between about 1% and about 5%, and the balance iron, said magnetic material having the magnetic properties produced in such a material by its being heated above a certain temperature, cooled slowly to a temperature near the magnetic transition point for that material, and then cooled rapidly at a rate intermediate an annealing rate and a rate at which undue stresses and strains will be set up in the material.

19. A magnetic material comprising approximately 78½% nickel, approximately 2% chromium, and the balance iron, said magnetic material having the properties produced in such a material by its being heat-treated by slowly cooling from 1100° C., followed by heating to 600° C., and then cooling rapidly to a point lower than the magnetic transition point of the material.

20. A magnetic material comprising nickel, iron and at least one other metallic element of melting point above 1150° C. in an amount not over 10% to give the material increased initial permeability, and in combination therewith an electrical conductor in inductive relation with said material, means whereby the conductor is caused to carry a current sufficient to produce in the material a magnetizing force not exceeding a fraction of a c. g. s. unit.

21. A magnetic material comprising approximately 78½% nickel, approximately 2% chromium, and the balance iron, and in combination therewith an electrical conductor in inductive relation with said material.

22. A loaded conductor comprising a conducting core having a layer of loading material wrapped helically thereabout, said loading material consisting of approximately 78½% nickel, approximately 2% chromium and approximately 19½% iron, the loaded conductor being subjected to a heat treatment to develop its optimum magnetic qualities.

23. A magnetic composition comprising chiefly two elements of the magnetic group in proportions which if used alone would permit high maximum permeability to be obtained and including additional material selected from the metallic elements of melting point above 1150° C. whereby the initial permeability is increased and the maximum permeability is decreased as compared with the same two elements of the magnetic group in the same proportions without the additional material, thereby making the permeability more constant for magnetizing forces up to the value at which maximum permeability is obtained.

24. A magnetic composition comprising chiefly two elements of the magnetic group in proportions which if used alone would permit high maximum permeability to be obtained and including additional material selected from the metallic elements of melting point above 1150° C. whereby the initial permeability is increased and the maximum permeability is not increased as compared with the same two elements of the magnetic group in the same proportions without the additional material.

25. A magnetic composition of initial permeability over 200 containing between 64% and 85% nickel and the balance chiefly iron plus an amount up to 8% of resistance increasing material selected from metals of melting point over 1150° C.

26. A magnetic composition of initial permeability over 200 in which nickel is present in an amount between 64% of the nickel-iron content and 85% of the entire composition and the balance chiefly iron plus an amount up to 8% of material of the chromium group of the periodic table for increasing the resistivity.

27. A magnetic composition of initial permeability over 200 in which nickel is present in an amount between 64% of the nickel-iron content and 85% of the entire composition, in which chromium is present in an amount from 1% to 8% and the balance is chiefly iron.

28. A magnetic composition of initial permeability over 200 comprising nickel and iron in proportions in which the nickel comprises from 64% of the nickel-iron content to 85% of the whole and additional material selected from the group of metals having a melting point above 1150° C. for making the permeability more constant than without the additional material.

29. A magnetic composition of initial permeability over 200 comprising nickel and iron in proportions in which the nickel comprises from 64% of the nickel-iron content to 85% of the whole and additional material up to 10% of the whole selected from the group of metals having a melting point above 1150° C. and forming a solid solution with nickel-iron compounds when present in amounts under 10% for reducing the hysteresis loss and increasing the constancy of permeability.

30. A composition in accordance with the foregoing claim in which said additional material is composed of elements of the chromium group of the periodic table.

31. A magnetic material comprising about 2% chromium, 64% to 85% nickel and the balance chiefly iron.

32. A magnetic composition heat treated to develop desirable magnetic properties at low magnetizing forces comprising chiefly nickel and iron in which the nickel lies between 65% of the total iron-nickel content and 85% of the whole, characterized in that from ½ to 10% of the entire composition is composed of material selected from the group of elements including chromium, molybdenum, cobalt, silicon and manganese.

In witness whereof, I hereunto subscribe my name this 1st day of August, A. D. 1925.

GUSTAF W. ELMEN.